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GEOLOGY, FACIES DISTRIBUTION AND ENVIRONMENTS OF THE CARBONIFEROUS STRATABOUND Mn DEPOSITS OF UM BOGMA REGION, SINAI, EGYPT

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ABSTRACT

The Mn deposits of Um Bogma region,Sinai, are confined to the lower Mn ore member of the Lower Carboniferous Um Bogma Formation and truncated together with the western coeval carbonates by the upper marine dolostone-shale member of this formation.

Field observations, sedimentological analyses and petrographical studies revealed that three general ore facies intertongue from east to west as follows: (a) stratiform continental Mn conglomerate, sandstone and mudstone of fining -upward pattern representing proximal facies of braided streams, b) stratiform lagoonal to swampy interbedded manganiferous mudstone and dolostone prevailing in the central part of Um Bogma region, and (c) near-shore pisolitic ore of coarsening upward tendency indicating deposition under a relatively high energy (storm~dominated) regime. Westwards, these Mn facies change into open marine carbonate facies associations. Stratabound karst Mn ore facies and related paleosol overprint the latter two ore facies, as a result of intra-Carboniferous paleokarstification processes.

It is concluded that Mn with Fe were derived from eastern hinterlands as clasts and suspensions that were deposited in channels along the coastal zone and debouched into the Lower Carboniferous sea depositing lagoonal to shallow marine manganiferous ore. A subsequent phase of uplifting and sea regression accompanied by karstification of the already formed manganiferous dolostone and mudstone led to the leaching and redistribution of the Mn and its concentration in the subsoil horizon of the resulted paleokarst profile. The geological setting of the recognized Mn facies and the host rocks reflects the paleotopography of the Um Bogma region, its tectonic instability during the Lower Carboniferous and the paleogeographic distribution pattern of the Lower Carboniferous sea.

1. INTRODUCTION

The present work deals with the stratabound Mn ore cropping out in westcentral Sinai (Um Bogma Region, Fig.1). It aims to elucidate the stratigraphic setting and mode of formation of this Mn ore as well as the regional and local geological parameters, which controlled its formation in this site. The obtained results are based on field observations including measurements of representative columnar sections and facies changes; focusing on the fossilized paleoerosion surfaces and related paleosols. Megascopic and microscopic observations, revealed the fabric characteristics of the different recognized ore types and the hosting sediments, and helped much in the recognition of the subenvironments in which these ore types were formed. Mineral composition of the recognized ore types is confirmed by XRD.

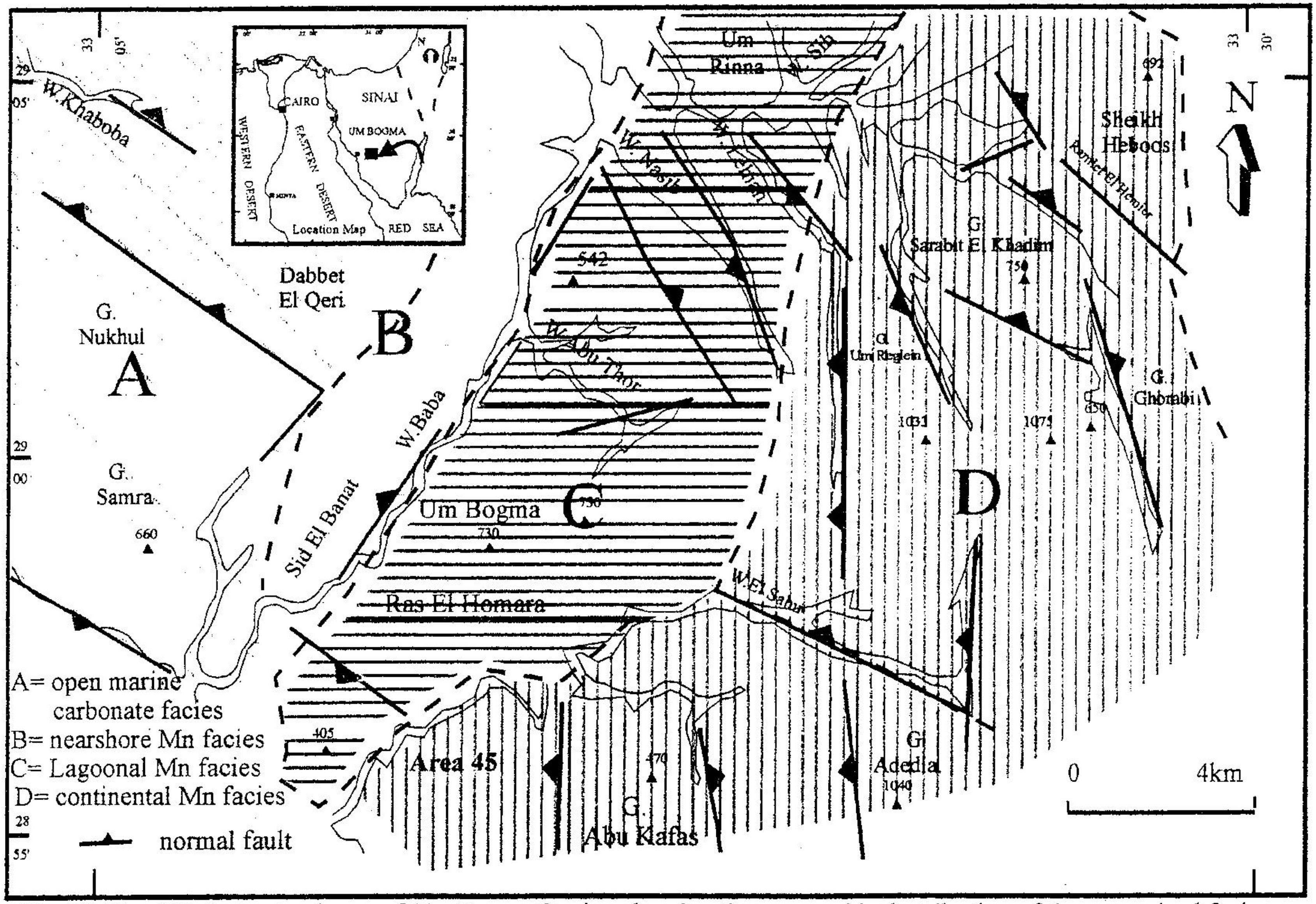

Fig. (1) Simplified structural map of Um Bogma Region showing the geographic destribution of the recognized facies of the lower Mn ore member of the Carboniferous Um Bogma Formation.

The tackling of the origin of the Mn ore of Um Bogma region and its prospecting has been the matter of long postulations since the last century. The main genetic theories proposed for Um Bogma Mn ore are recently reviewed and discussed by El Sharkawi *et al.* (1990 a &b) and El Aref (1994). Several hypotheses were postulated, among which are: a) epigenetic hydrothermal origin related to the Oligo-Miocene volcanicity (e.g. Gindy, 1961; Said 1962; Soliman, 1961 & 1963 and Hassan *et al.*, 1990), b) marine sedimentary origin (e.g. El Shazly *et al.* ,1963; Mart and Sass, 1972 ; Magaritz and Brenner ;1979; Saleeb *et al.*, 1987 and Kora *et al.* ,1994 , and c) karst origin as suggested by Abdel Motelib (1987) and El Sharkawi *et al.* (1990 a).

Detailed studies on the Carboniferous Um Bogma Formation and the associated Mn ore proved that the karst Mn ore is overprinted on stratiform lagoonal bedded manganiferous mudstones and dolostones in the central part of Um Bogma region. In the eastern part of this region, the lagoonal manganiferous sediments intertongue with and grade into stratiform continental channel fill Mn conglomerate, sandstone and mudstone. In the western part, these lagoonal sediments change into stratiform coarsening-upward sequences of bedded pisolitic Mn ore. In the northwestern part of Um Bogma region, the manganiferous sediments are replaced by a continuous section of marine fossiliferous carbonates and shales.

2. GEOLOGICAL SETTING

Um Bogma region (Fig. 1) is built up of Late Proterozoic metamorphic and igneous rocks, which are unconformably overlain by a heterogeneous thick succession of Cambrian and Lower Carboniferous sediments, and are intersected by Late Paleozoic-Early Mesozoic volcanic eruptions. This region is characterized by highly mountainous areas (Fig.1), separated by nearly flat areas covered by wind blown sands, e.g. Dabbet El Qeri (450 - 500 m a.s.l) and Ramlet Hemeiyir (550 m a.s.l).

The Precambrian crystalline basement rocks are cropping out in the western part of Wadi Khaboba and also along the south and southeast parts of the region, along Gabal Samra, W. Baba and W. Shalal (Fig. 1). In the eastern and northern parts of the area, the crystalline rocks are highly denudated and disappear under Paleozoic, Mesozoic and Cenozoic sedimentary successions. The Paleozoic sediments are represented by two clastic sequences separated by a dolostone-shale sequence hosting the Mn Ore. Due north of Um Bogma region, at El Tih and Egma plateaux, these Paleozoic sediments are bounded by a thick post-Carboniferous (Mesozoic to Early Cenozoic) clastics and carbonates. Due south, towards W. Feiran, the Paleozoic sediments of Um Bogma region are facing the mountainous belt of the Precambrian crystalline rocks of W. Feiran and Sant Kathrina.

The Cambrian succession of Um Bogma region is formed of the Araba Formation at the base followed upward by the Naqus Formation (Figs.2 & 3). The Araba Formation (10-70 m thick, = Sarabit El Khadim and Abu Hamata formations of Soliman and El Fetouh, 1969) follows unconformably the crystalline basement rocks and represents the first Paleozoic transgressive phase in the region. It is formed entirely of clastics rich in trilobite and bilobite tracks of fluvial to near shore shallow marine environments. The Naqus Formation (0-60 m thick, = Adedia Formation of

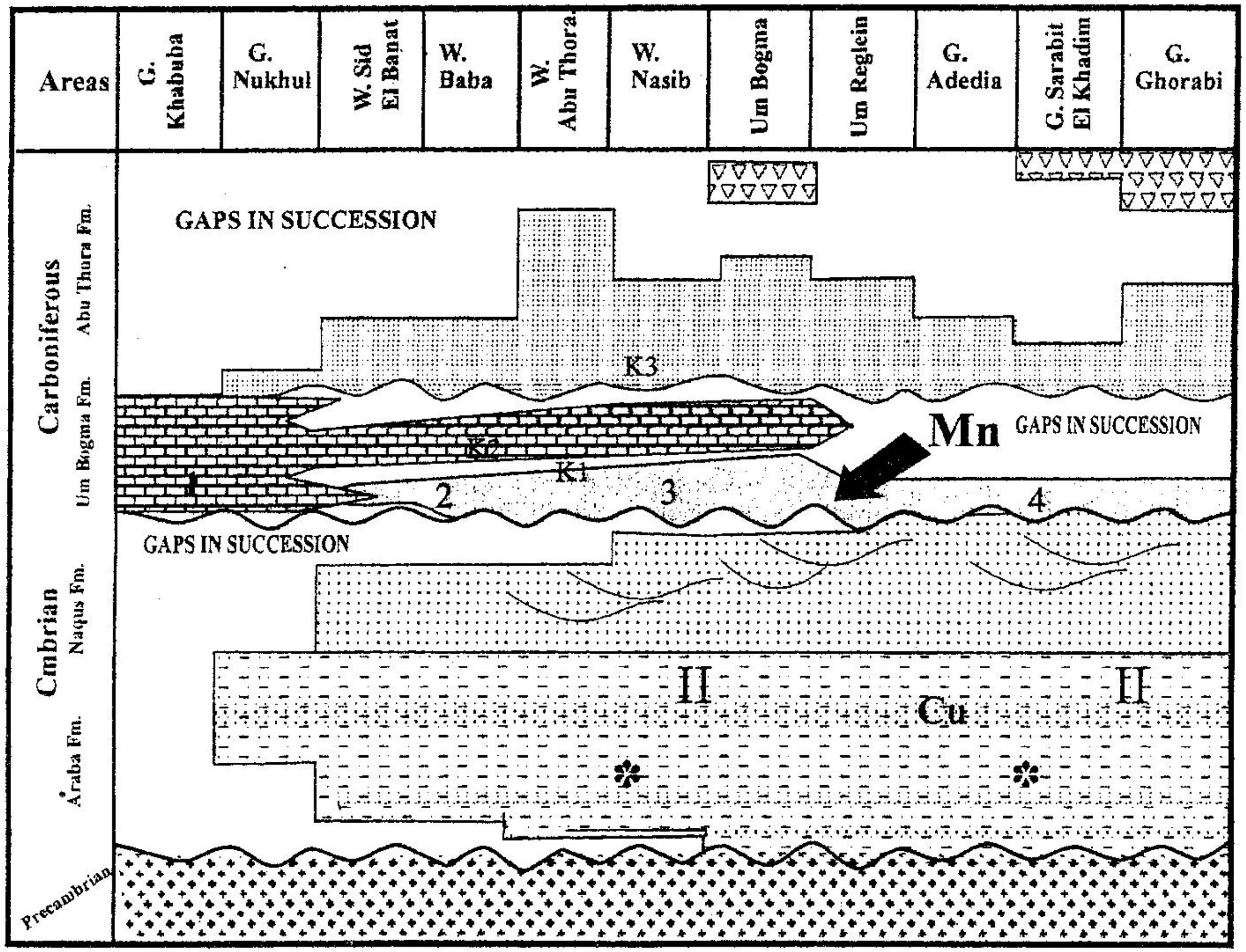

Fig.(2): The different gaps intervene the Paleozoic sediments of Um Bogma Region and the stratigraphic setting of the Carboniferous Mn ore types (facies).
1= marine carbonates ; 2= near shore Mn ore ; 3= lagoonal Mn ore ; 4= continental Mn ore
K1 & K2 = intra-Um Bogma paleokarst surfaces ; K3= post-Um Bogma paleokarst surface
✽ = fossil tracks (*Cruziana*) , II= *Skolithos,*

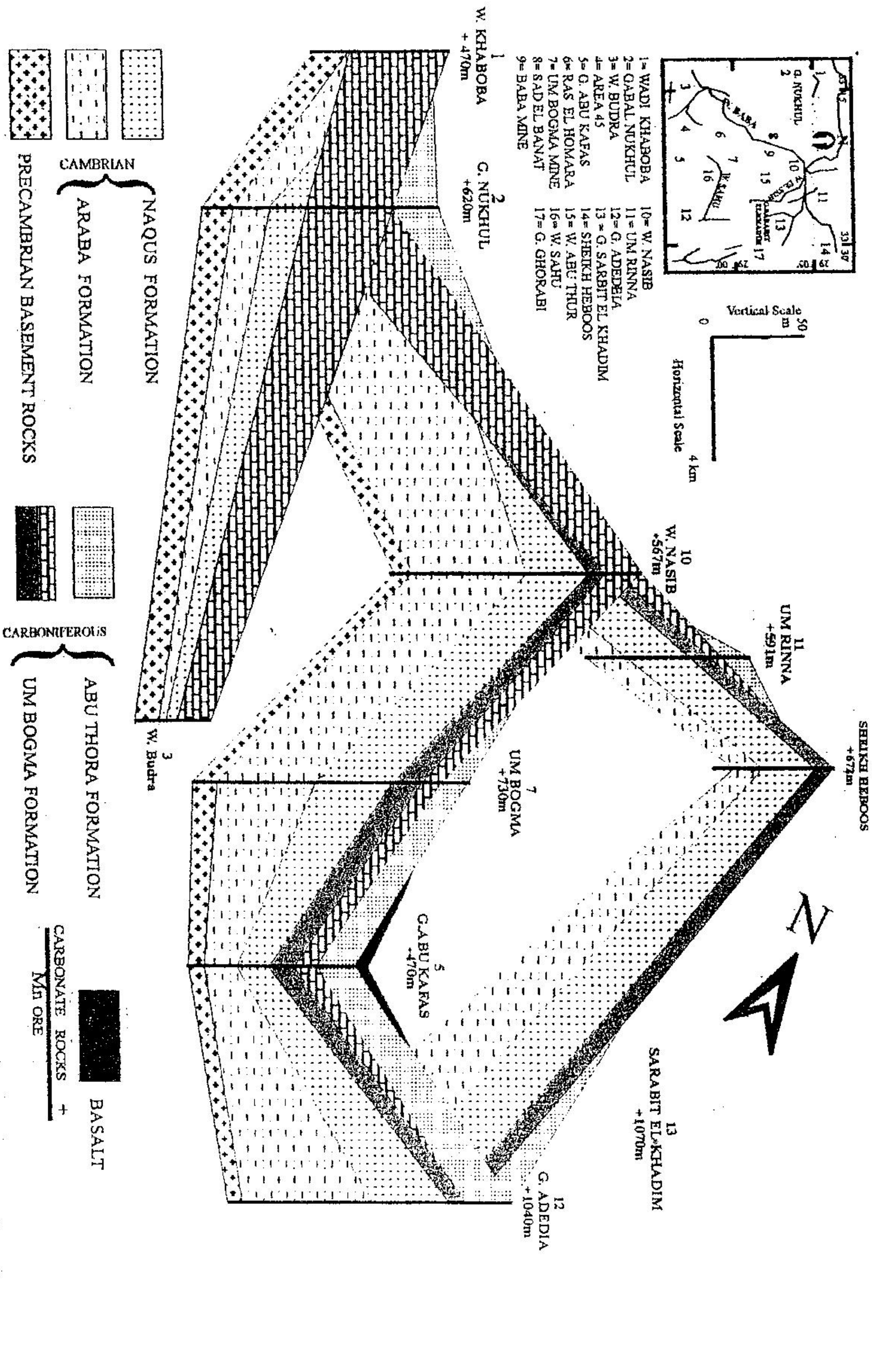

Fig. (3) : Isometric panel diagram of the different Paleozoic rock unites of Um Bogma Region, west-central Sinai, Egypt.

Soliman and El Fetouh, 1969) rests on different stratigraphic horizons of the Araba Formation and consists of gravely sandstones and conglomerates with some intercalated red to brown mudstone layers of fluvio-continental environment indicating a continuous shallowing of the marine sequence of the Araba Formation. The existence of the fluviomarine Cambrian succession of Araba and Naqus formations in Um Bogma region is attributed to the paleogeography of the Cambrian sea which advanced over the northern part of Egypt (Schandelmeier *et al.* 1987 and Klitzsch *et al.,* 1990).

At the beginning of the Paleozoic Era, Egypt as a part of Gondwana land was drifted southward reaching paleolatitude 70^0S (Smith, 1981). During Ordovician, Silurian and Devonian time span, Egypt was bounded by epicontinental sea (Semtner and Klitzsch, 1994). This sea transgressed and covered only the southwestern part of Egypt (Klitzsch and Legal-Nicol, 1984 & Burollet, 1960). The remaining parts of Egypt, including Um Bogma region were positive lands under erosion.

During the Lower Carboniferous, the sea transgressed over the study area depositing the Mn ore bearing Um Bogma Formation (Figs.2 & 3). This was followed by a regressive phase depositing the overlying fluviomarine Abu Thora Formation.

The Um Bogma Formation and the enclosed Mn ore are of limited distribution and are restricted only to Um Bogma region. This formation is of varying thickness (0 - 45 m) and truncates different stratigraphic horizons of the Cambrian Araba and Naqus formations. South of Um Bogma region, at W. Feiran, W. Mokattab and G. Abu Durba, Um Bogma Formation is completely missing, and the overlying Abu Thora Formation overlies directly the Cambrian Naqus Formation (Klitzsch, 1990 and El Barkooky, 1992). At northern W. Qena, Eastern Desert, Abu Thora Formation also rests directly on the Cambrian Naqus Formation (Abdallah *et al.* 1992). Along the western side of the Gulf of Suez, at W. Araba, only the Upper Carboniferous - Permian shallow-marine and continental successions of Rod El Hamal, Abu El Darag and Eheimar formations (Abdallah and Adindani, 1963 & Abdallah, 1992) are exposed while Um Bogma Formation is absent. At the southwestern corner of the Western Desert (G. Uweinat), the Lower Carboniferous Wadi Malik Formation consists of fluviatile shallow-marine clastics followed by the Upper Carboniferous fluvioglacial sediments of North Wadi Malik Formation (Klitzsch and Wycisk, 1987). This overview may reflect the tectonic instability of Um Bogma region during the Lower Carboniferous time, and may explain the confinment of the Lower Carboniferous shoreline to this region (El Aref ,1994).

The Abu Thora Formation is formed of cross bedded gravely sandstones, sandstones and mudstones with occasional coaliferous beds at the top of the formation, and is believed to be deposited in continental to near shore paralic environments.

The Permo-Triassic basaltic eruptions of Um Bogma region form sheet ike bodies over the clastic sediments of the Abu Thora Formation at the Um Bogma type locality, and due east at G. Chorabi and towards the south at G. Farsh El Azraq. Also basaltic dykes of this phase of volcanicity cut across all the described rock units and the associated Mn ore varieties.

Faults are the main structural elements that left their prints on the rocks of Um Bogma region (Fig.1). They can be grouped into the following: a) NNW-SSE trending normal faults (Red Sea trend) along which the Permo-Triassic basaltic dykes were

erupted. b) NW-SE trending faults (Gulf of Suez trend) along which the main wadies of the Um Bogma region were incised, e.g. W.Nasib, W.Baba, W. Bala and W. El Lehian. These faults were responsible for the development of grabens and horsts and juxtaposition of different Paleozoic stratigraphic units. Along the Gulf of Suez, this fault system brought the Precambrian and/or Paleozoic rocks against the Cretaceous - Miocene successions, and c) E-W trending faults along which W. Sahu, W. Abu Thora and were incised. This fault system together with the NW-SE faults were responsible for the uplifting of G. Samra - G. Nukhul, W. Baba-Sid El Banat, Um Bogma - W. Nasib, G. Um Reglein, Adedia, G.Chorabi - G.Sarabit El Khadim blocks.

3. LITHOLOGY AND ENVIRONMENT OF THE HOST UM BOGMA FORMATION

The Um Bogma Formation (0-45 m thick) unconformably overlies the sediments of the Naqus Formation every where in the Um Bogma region (Figs.2 & 3) except in the western area of W. Khaboba where a considerable thickness of the Um Bogma Formation rests directly over thin section of the Araba Formation or the Precambrian rocks. The present work on Um Bogma Formation revealed that it could be subdivided into two members: a) a lower Mn ore member and b) an upper dolostone-shale member. Erosion features (solution dolines and channels) dominate the contact between these two members and soil products mixed with collapse breccia fragments. The different rock types and microfacies associations of these members are shown in table 1.

The lower Mn ore member is formed of an open marine facies association of bedded sandy dolostone, shales and dolostones towards W. Khaboba and G. Nukhul It dominated by wackestone, packstone and grainstone facies, resembling the open marine facies Nos. 2 and 7 of Wilson (1975). In the central part of Um Bogma region (e.g. W. Baba, G. Sid El Banat, W. Abu Thor, W. Nasib, Um Bogma type locality, Ras El Homara, Area 45, G.Abu Kafas and W. Sahu, Figs.2 & 3), these rocks grade into manganiferous mudstones, stratiform pisolitic Mn ore and bedded manganiferous dolostone of lagoonal environment (Fig.4). Towards G. Um Reglein, G.Adedia, southern parts of G. Sarabit El Khadim and G. Ghorabi, the lagoonal associations intertongue with and change into continental channel fill Mn conglomerate, sandstone and mudstone. Paleokarstification processes acted upon the lagoonal manganiferous mudstones and dolostones of the Lower Mn ore member and resulted in the enrichment and redeposition of Mn crusts and concretions along the paleokarst surface and within the subsurface solution features (**K1**, Fig.5).

The lower member of the Um Bogma Formation and its lithofacies associations and karst products were truncated by an intercalation of fossiliferous dolostones and shales of tidal flat and open marine environments, comprising the upper dolostone-shale member of this formation. The rocks of this member were interrupted by a short-lived karst surface (**K2**, Figs. 4 & 5) and terminated by another paleokarst (**K3**), which is unconformably overlain by the clastic sediments of the Abu Thora Formation. The extension of this member is dying out towards the east and south, where the overlying Abu Thora Formation rests directly over the Lower Mn bearing member of the Um Bogma Formation or the clastic rocks of the Naqus Formation (Figs. 2 -5). The upper carbonate member is dominated by the following microfiches: sandy argillaceous xenotopic oolitic grainstone, highly fossiliferous shale, argillaceous echindoidal wackestone-packstone, brachiopod packstone, sandy

grainstone, oolitic grainstone and karstified bioclastic packstone microfacies. This association indicates deposition in normal marine to restricted platform environment followed by a regressive phase and processes of post- Um Bogma paleokarstifikation (**K3**, Figs. 2-5).

Table (1): The different ore types and microfacies associations of the Um Bogma Formartion

	Western Facies	Central Facies		Eastern Facies
	W. Khaboba G.Nukhul	Sid El Banat W. Kharig	Um Bogma W. Nasib	G. Sarabit El Khadim G.Adedia
Upper Member	oolitic Grst		sandy dolitic Grst	
	fossiliferous shale			
	argillaceous echinoidal Wkst - Pkst			
	brachipod Pkst			
	paleokarst			
Lower Member	fossiliferous shale Grst sandy oolitic Grst	paleosol pisolitic Mn ore	paleosol bedded Mn dlostone & mudstone	paleosol Mn cong., ss. & mdst.

Grst= grainstone; Pkst= packstone; Wkst= wackestone; Mdst= mudstone; cong.= conglomerate; ss= sandstone. (Detailed description in Abdel Motelib, 1996).

4. Mn ORE FACIES (TYPES)

The present field observations and the focus on the lower Mn ore member of the Um Bogma Formation revealed that four general ore types (facies) intertongue from east to west as follows:

1. Stratiform continental channel fill Mn conglomerate, sandstone and mudstone
2. Stratiform lagoonal to swampy bedded manganiferous mudstones and dolostones
3. Stratiform pisolitic Mn ore, and
4. Stratabound karst ore.

4.1. Stratiform Continental Channel Fill Mn Onglomerate ,Sandstone And Mudstone

This Mn ore type is well represented in the eastern and southeastern localities of Um Bogma region, e.g., G. Adedia, southeastern part of G.Sarabit El Khadim, Sheikh Heboos area and G. Chorabi.(Figs. 1,4 & 5) reaching up to 7m in thickness. It forms stratified small-scale fining - upward sequences of Mn-conglomerate, cross-laminated Mn sandstone and nodular manganiferous and ferruginous mudstones. At Gabal Chorabi and G. Adedia, the thickness of this ore type is reduced to 2 m only.

The Mn conglomerates make up a substantial proportion of the overall thickness of this ore facies and form laterally discontinuous beds or lenses, up to 50 cm in width and 10 cm thick, rimmed and topped by Mn sandstone and/or ferruginous mudstone. They form with the associated sandstones and mudstones multicycles of fining-

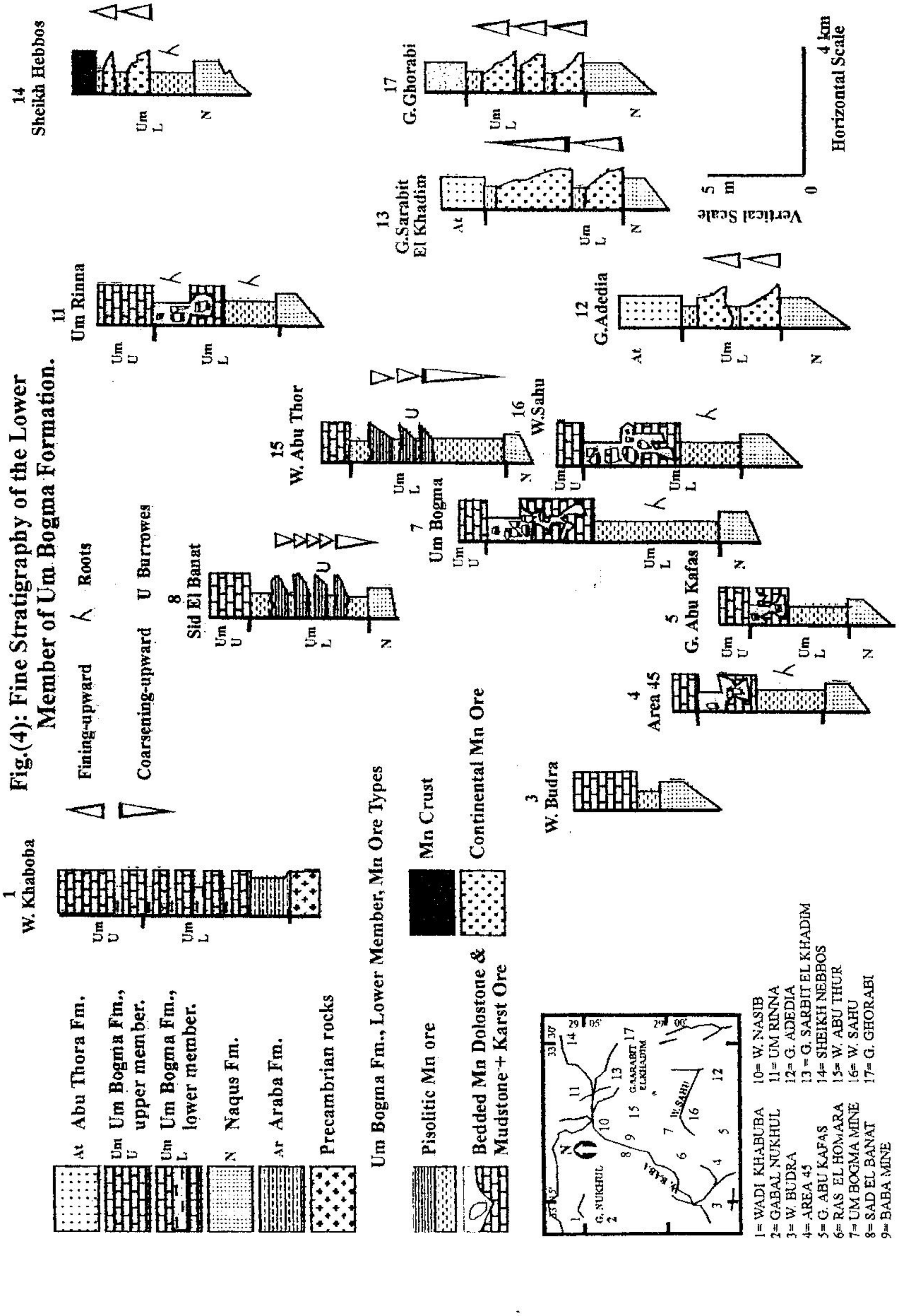

Fig.(4): Fine Stratigraphy of the Lower Member of Um Bogma Formation.

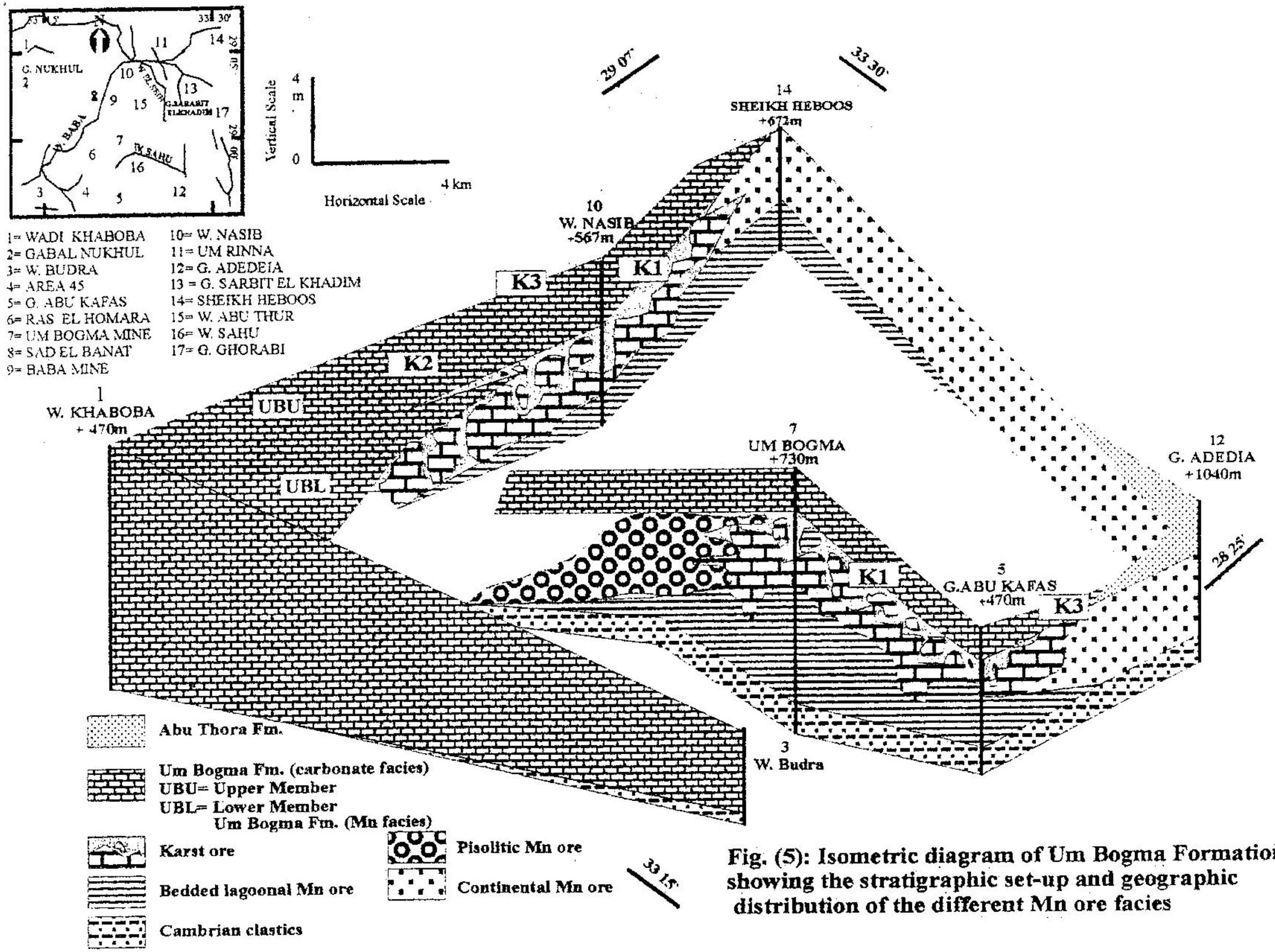

Fig. (5): Isometric diagram of Um Bogma Formation showing the stratigraphic set-up and geographic distribution of the different Mn ore facies

upward sequences often interrupted by reactivation surfaces dominated by cut and fill structures (Fig.6). They are made up of angular to subrounded Mn grains and rock fragments, up to 3 cm in diameter, Fe concretions of rounded to subrounded forms, up to 6 mm in diameter, and quartz pebbles, up to 5 mm in diameter, immersed in an earthy Mn rich matrix. Clasts/matrix ratio is high and the clasts are often tightly stacked against one another suggesting deposition from braided tributaries of proximal facies. Some grains show partial or complete coating rims by pyrolusite. The cementing materials are mainly formed of colloform encrustations made up of bladed prismatic crystals of pyrolusite or polianite of subparallel to parallel habit, which show strong anisotropism and lamellar twining. Crustified rhythmic layers made up of pyrolusite and manganite, or blocky mosaic pyrolusite are also present. Obliteration and brecciation due to dehydration during late cementation stage by barite and/or calcite are very common.

The Mn sandstone refers to cross-laminated sandstone of quartz grain composition being cemented by Mn oxide. It is formed of rounded to subrounded grains of quartz, up to 1 mm in size, moderately sorted. detrital Mn -rich pebbles are frequently present as lags along troughs of cross sets. These pebbles are subjected to several generations of reworking and redeposition as they often show signs of *in situ* brecciation, reworking and redeposition. Such Mn sandstones may represent a foreset channel fill cross-strata accompanied by a decrease in the volume of framework of the detrital Mn conglomertes and relatively increase in the sandy fractions.

The laminated nodular Mn mudstones are recorded in the topmost parts of the fining-upward sequences and represent a culmination period that prevailed during the end of the deposition of the clastic sequence. They are composed of hematite nodules embedded in red kaolinite with minor quartz grains and Mn rich encrustations of pyrolusite composition. Nodular hair-like forms of massive romanechite core and radial pyrolusite are also present. Under the microscope, hematite forms dendritic leaf-like or cellular structure immersed in organic rich kaolinite and is topped by rhythmic colloform pyrolusite encrustations. This texture indicates formation during dewatering process and early diagenesis. The topmost Mn mudstone bed (up to 30 cm thick) is characterized by the abundant distribution of coaliferous materials. The Mn -rich mudstones are usually intercalated with or laterally changes to Fe -rich mudstones being composed of rhythmic arrangement of red kaolinite and earthy iron rich materials (yellow to red ochres) with moderately sorted, subrounded to subangular sand quartz grains.

The fining-upward tendency of this conglomeratic ore type, its framework components and the composition of the matrix, together with the erosive soles of the conglomerate layers, all characterize surface slope deposits accumulated through mud flow regime (Reading, 1978) and refer to the derivation of these materials from nearby or contiguous source. The fining-upward pattern of this ore type is accompanied by a gradual decrease in thickness from Mn conglomerate to mudstone with a decrease in the volume of the detrital Mn fragments and a relative increase in the sandy fraction. These features are interpreted as being the products of braided tributaries of streams which emerged from internal drainage into the fan surfaces as foreset and trough fill cross strata (Reading, 1978).

4.2. Stratiform Lagoonal To Swampy Manganiferous Mudstones And Dolostones

This Mn ore type unconformably overlies the Cambrian Naqus Formation at the central part of the Um Bogma region, e.g. at W. Nasib, G. Abu Kafas, Um Bogma

type locality, W. Baba, Area 45 and Ras El Homara -W. Sahu (Figs.4 & 5). It forms a stratified sequence beginning with manganiferous and ferruginous mudstones at the base and terminating upward by cyclic rhythmically alternating beds of hard manganiferous dolostone and softer manganiferous mudstone. The lower erosive contact of these beds with the underlying clastics of the Naqus Formation is characterized by the dominance of clastic influx, up to 30 cm thick. This contact is made up of manganiferous and iron rich concretions with sand-sized Mn ore fragments embedded in loose matrix of ochreous composition of yellow to brownish red colour. The lower manganiferous and ferruginous mudstone beds consist of nearly continuous layers of brownish to reddish brown and black colours, attaining up to 5 m thick. They are usually laminated and sooty and are made up of earthy sesquioxides of Mn and Fe with abundant organic remains .The lamination and bedded nature of these mudstones are mainly due to colour variations, grain size, and chemical composition differences. The individual beds is intersected by fine veinlets filled with pyrolusite, goethite and/or barite. These veinlets are confined within individual layers and usually end at the layer boundaries. The Mn-mudstone layers are sometimes intercalated with laminated and nodular evaporites. The overlying rhythmically alternated manganiferous mudstones and dolostones attain up to 4 m in thickness. The manganiferous dolostones form dense and massive beds, 20-50 cm thick, of pinkish gray to brown colour exhibiting dark reddish violet tarnish on the weathered surfaces and gradational contacts with the intercalated manganiferous mudstones. They are highly karstified and collapsed and often capped by bauxitic paleosol (El Sharkawi *et al*, 1990 a,b; Hussein *et al.* ,1998 and El Aref *et al.* 1998).

The manganiferous mudstones consist of alternating laminae of earthy Fe-rich clays and pyrolusite. Pyrolusite occurs as tabular crystals with lamellar twinning and distinct cleavage or forms spherulites surrounded by yellowish brown to red calcareous mud intermixed with kaolinitic clays, iron rich and oxidized filaments and roots of organic origin. The manganiferous dolostones are highly disrupted and brecciated due to intensive subsequent karstification. Relicts of the intact well-bedded parent rocks including evaporite nodules are recorded in some undisturbed sites, particularly along the basal part of the induced karst profile. They are also found as disconnected bodies of variable diameters within collapse breccia and residual soily materials along cave walls, ceilings and floors (El Sharkawi *et al.*1990 a,b).The original rocks are often stylolitic and consist of dolomitized micrite pellets and calcareous ooids cemented by colloform calcite and pyrolusite and blocky calcite crystals. These components are partially to completely replaced by closely packed, coarse-grained and zoned ferroan dolomite crystals, up to 0.3 mm across, idiotopic to hypidotopic with prominent iron and manganese rich cloudy inner zones and iron poor outer rims. The interlocked ferroan dolomite crystals exhibit well-developed sugary or saccharoidal texture. As a result of dedolomitization, the ferroan dolomite crystals are highly corroded by calcite and/or floated in poikilotopic calcite. Selective dissolution of the carbonate matrix resulted in the formation of microscopic solution cavities filled with crustified pyrolusite with or without romanechite, dolomite and quartz.

The Mn and Fe mudstones suggest deposition from suspension in low energy conditions of lagoonal environment (Pettijohn, 1975). The earthy materials and the sooty Mn components of this facies as well as the associated organic materials represent transported continental soil materials by action of paleodrainage. The manganiferous dolostone was probably deposited in a shallow shelf lagoon enriched

by land-derived Mn and Fe sesquioxides and in association with marine influx rich in Mg and Ca cations. The alternation with evaporitic sediments is rather an indication for deposition in a restricted lagoonal environment of high salinity and high evaporation..The depositions of Mn mudstone and dolostone layers appear to be interrupted by periods of meteoric splash water intermixing with seawater. In these periods, the conditions were favorable for the formation of the late diagenetic ferroan dolomite (Badiozamani, 1973; Fuchtbauer, 1974 and Tucker *et al.*, 1990). The prevalence of splash meteoric water with continuous uplifting gives rise to the development of karstification, dedolomitization and formation of the stratabound Mn karst ore.

4.3. Stratiform Pisolitic Mn Ore

This pisolitic Mn ore type constitutes the lateral faciese equivalent to the above described ore types; namely the stratiform Mn conglomerate, sandstone and mudstone and the startiform manganiferous mudstone and dolostone. It attains up to 5 m thick and is recorded in limited localities, at W. Abu Thor and G.Sid El Banat (Figs, 4 & 5). This ore type unconformably overlies the Naqus Formation, and is terminating upward by a highly undulated erosive surface being dominated by paleosol of nodular kaolinite, gibbsite and alunite mixed with yellow to red ochres. This paleosol interval can be correlated with that of the topsoil horizon of the karst ore separating the Mn ore member from the overlying dolostone-shale member of Um Bogma Formation (**K1**, Figs.2, 3 & 5). The pisolitic ore is fairly bedded and consists of small-scale, 30-80 cm, coarsening-upward sequences reflecting deposition during cyclic shallowing regimes. Each sequence starts at the base by bioturbated manganiferous or ferruginous mudstone rich in organic matter and evaporites showing shrinkage features, ripple marks and flaser structure. The basal mudstones suggest deposition from suspension in a generally calm environment and grade upward into a pisolitic (oncolitic?), storm-generated bed or coarse lag corresponding to the storm-generated capping-bed of Cotter and Link (1993) and suggest deposition in a relatively. High energy depositional regime prevailing during regressive periods and consists of ill-sorted, matrix to grain-supported pyrolusite-goethite pisoliths, coarse skeletal fragments and fossil moulds immersed in a matrix of earthy Mn oxides recrystallized into idiomorphic fine-grained pyrolusite.

4.4. Stratabound Karst Mn Ore

The karst Mn ore is confined mainly to the Lower Carboniferous, intra-Um Bogma paleokarst (**K1**). It is recorded in the central part of Um Bogma region, e.g. at W. Nasib, W. Baba, Area 45, G. Abu Kafas, Um Rinna, Um Bogma type locality and Ras El Homara localities (Figs.2, 4 & 5). In these localities, this ore type is overprinting and obliterating the stratiform-bedded manganiferous and ferruginous mudstones and dolostones. The thickness of the karst ore is not constant all over the studied sections (Fig. 4). This variation in thickness delineates the paleotopography and reflects the intensity of the paleokarstification. In Um Bogma type locality, the thickness of the paleokarst profile may reach up to 6 m.. A series of solution depressions and channels of variable diameters dominate the uppermost part of this profile.

The karst profile is subdivided into three main horizons, each horizon is characterized by a distinct pedogenic rock composition and fabrics (Abdel Motelib, 1987; El Sharkawi *et al.* 1990 a,b; Hussein *et al.* 1998 & El Aref *et al.*, 1998).

These horizons are:

a) **A lower horizon** (parent rocks) of interbedded ferruginous and manganiferous mudstones and dolostones ,

b) **Subsoil horizon**, 2 to 4 m in thickness, (= illuvial or B horizon) consisting of highly karstified manganiferous rocks dominated by numerous solution features. As a result of illuviation processes, the subsoil horizon hosts reprecipitated Mn ore as intra-karstic precipitates, filling the subsurface solution features and forming crustified layers, speleothems, nodules and cave pearls. The upper part of the subsoil horizon is covered by Mn conglomerate mixed with melon-shaped boulders and concretions of Fe and Mn composition, either coalesced with each other, or present as individuals immersed in kaolinite matrix, and

c) **Topsoil horizon** of acidic latosol (= leaching; eluvial or A horizon) rich in nodular kaolinite; gibbsite, alunite and red ochres together with complex copper and uranium phosphates, silicates, carbonates, chlorides, vanadates and sulphates.

The development of this paleokarst profile indicates that the central part of Um Bogma region was uplifted soon after the deposition of the lagoonal manganiferous mudstones and dolostones. This uplifting phase was accompanied by a general lowering of the sea level and subjection to intensive karstification under humid paleoclimate followed by a general desiccation of the weathering profile.

5. CONCLUSIONS

Carboniferous stratabound to stratiform Mn-ore types are confined within the Lower Carboniferous succession of the Um Bogma Formation, westcentral Sinai. These Mn-ore types have been deposited by the combined action of subaerial and shallow marine conditions prevailing along the Carboniferous paleoshoreline and paleokarstification related to intra -Carboniferous uplifting phase, sea level fall and deep weathering processes.

The lower Mn ore member of Um Bogma Formation is formed of different ore types, which grade laterally into open marine carbonates. The equivalent carbonates are composed of wackestone, packstone and grainstone microfacies associations, which reflect neritic shelf to open marine environment. The carbonates of the overlying ore member encompass grainstones and bioclastic packstone microfacies reflecting deposition in open platform environment.

The recognized Mn-ore types of the lower member of Um Bogma Formation are subdivided into the following:

1) stratiform continental Mn-conglomerate, sandstone and mudstone
2) stratiform lagoonal to swampy bedded manganiferous mudstone and dolostone
3) stratiform pisolitic Mn ore
4) stratabound karst Mn ore.

The stratiform continental Mn-conglomerate, sandstone and mudstone exhibit fining-upward textures and represents surface slope deposits (channel fill) accumulated through mudflow regime. It refers to the derivation of Mn & Fe -rich materials (as clasts or suspensions) from nearby or contiguous sources. The lateral gradation of this ore type into lagoonal pisolitic and bedded Mn ore facies implies the north and westward debauching of the land-derived Mn-rich materials into the Lower

Carboniferous sea. This may suggest that detritus Mn and Fe materials (clasts and suspensions) were probably derived from precursor ore developed on paleohighs, east and southeast of the study area under humid paleoclimate.

The stratiform lagoonal to swampy manganiferous mudstones and dolostones form a stratified sequence consisting, within its lower part, of laminated and concretionary manganiferous and ferruginous mudstone which grades upward into rythmically alternated manganiferous mudstones and dolostones. It is well represented in the central and northwestern parts of Um Bogma region. The stratiform nature of these manganiferous mudstones and dolostones interbeds, their primary sedimentary structures, nodular and laminated evaporite intercalations, speculate about their synsedimentary origin and indicate their deposition in a restricted lagoonal (sabkha) environment of high salinity subjected to strong evaporation. The Mn and Fe-rich earthy materials of this ore type represent transported continental soil while the carbonate interbeds and their oolitic and pellitic characters reflect marine conditions. The formation of coarse-grained zoned ferroan dolomite may indicate the prevalence of splash water intermixing with marine water. On the other hand, dedolomitization, replacement of dolomite by calcite and pore filling processes are attributed to the effect of fresh water diagenesis during uplifting and paleokarstification of these rocks.

The stratiform pisolitic Mn ore reflects deposition during cyclic shoaling regimes as it consists mainly of coarsening - upward cycles of basal manganiferous mudstones grading upward into pisolitic beds. The mineralogy and textures of the ore components reflect their continental source and their transportation to the medium of deposition.

The stratabound karst ore was formed during intra-Carboniferous deep weathering processes inducing karstification, following or contemporaneous with a phase of sea level fall and exposuring of the aforedescribed bedded manganiferous mudstones and dolostones. This regressive phase and the related paleokarstification preceded the subsequent sea transgression, which led to the deposition of the overlying upper dolostone-shale member of the Um Bogma Formation. The paleokarstificaflon processes led to the development of a typical deep weathering profile comprising an upper topsoil horizon (leaching horizon); a middle subsoil horizon (Mn-enriched horizon) hosting the redeposited Mn ore and a lower slightly karstified parent rocks.

Summing up, paleogeography of the Carboniferous shoreline, the paleotopographic evolution of Um Bogma region during the Lower Carboniferous, together with sea level changes, paleoclimate and paleoenvironment controlled to a large extent, the concentration of the Mn ore within the lower member of Um Bogma Formation. It is suggested that Mn be derived from eastern hinterlands as clasts or suspensions that deposited in channels along the coastal zone and debouched into the Carboniferous Sea. A subsequent period of sea regression accompanied by karstification on of the already formed manganiferous dolostones and mudstones led to the redestribution of manganese and its concentration in the subsoil horizon of the paleokarst profile.

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